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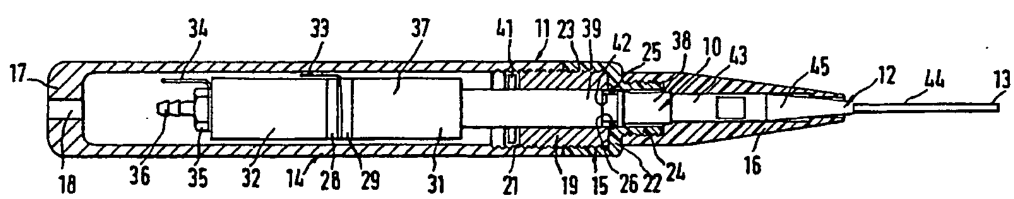
(54) Hand Held Ultrasonic Transducer Instrument

(57) An instrument has a hollow casing (11), which is held by hand when the instrument is used, and a tool (12) having a tip (13) outside the casing (11). The tool (12) is part of a mass-loaded ultrasonic transducer system which also includes a mass-loaded piezoelectric ultrasonic transducer (28, 29) and a stepped ultrasonic vibration transmitter and amplifier (31). The transmitter and amplifier (31) supports the tool (12) and abuts the transducer so that it transmits to the tool (12) ultrasonic vibrations generated by the transducer and amplifiers those vibrations whilst transmitting them. The mass-loaded piezoelectric transducer and at least a major part of the stepped ultrasonic vibration transmitter and amplifier (31) are housed within the casing (11).

The drawing originally filed was informal and the print here reproduced is taken from a later filed formal copy.



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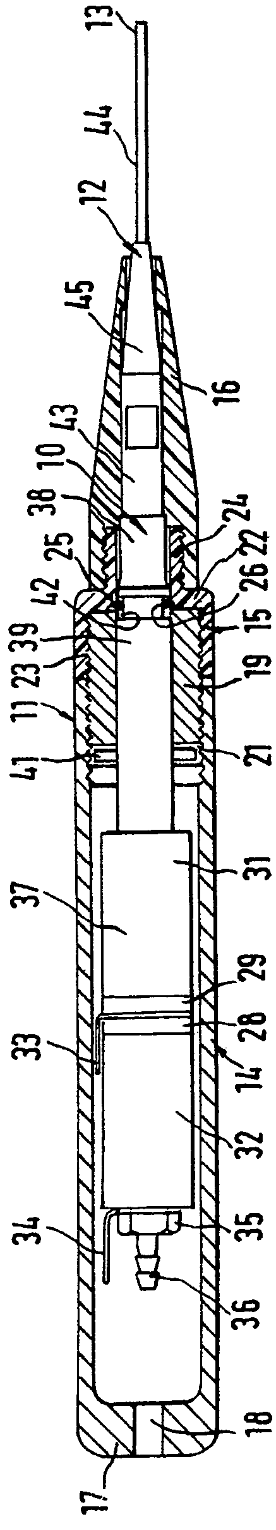
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SPECIFICATION

An Instrument Including an Ultrasonic Transducer System

This invention relates to instruments of the kind which comprise a casing which is to be held by hand when the instruments is in use and a tool which has a tip outside the casing and to which ultrasonic vibrations are transmitted by an ultrasonic transducer system when the instrument is in use. Such instruments are used, for example, as surgical instruments. The tool may be detachable and may have been selected for a particular use from a range of different tools such as tools having cutting, scraping or dispensing tips.

An object of this invention is to provide an efficient and compact ultrasonic transducer system housed in an instrument which is to be held in the hand when in use.

Ultrasonic transducer systems generally constitute a means of converting an alternating electrical signal into a mechanical vibratory output. The frequency of vibration is usually the electrical frequency or a harmonic of this frequency.

The method of conversion can take a number of forms, but is generally based on the magnetostrictive effect found in certain metals, or the piezoelectric effect exhibited in various crystals.

The application of an electric field to a piezoelectric crystal with the field applied in a particular direction results in a mechanical deformation of the crystal. The cancellation of the electric field allows the crystal to return to its original state. Thus an alternating electric field produces a corresponding alternating mechanical deformation.

The amount of deformation in most piezoelectric materials is of small magnitude but the resultant amplitude of vibration can be increased by using a resonant amplifier, which is known as a waveguide and in which the area over which the output vibration occurs is smaller than the area of the element of piezoelectric material in which the vibrations were generated. The section joining the two areas has a mathematical form conforming to the linear wave equation and based on harmonic wave motion.

The acoustic design of such a multisection transducer system generally requires each section to be resonantly matched as half-wave resonators. It will be understood that the end of each section will constitute an anti node with maximum amplitude and the acoustically linear centre or quarter wave plane will be a node of minimum amplitude. This implies that the piezoelectric element is a half wave vibrator but its thickness would be impractical. By mass loading at the rear of the element it is possible to reduce the thickness to a practical value. The length of the mass combined with the thickness of the element will define the resonant frequency of this half-wave section.

According to this invention there is provided an instrument comprising a hollow casing, which is to be held by hand when the instrument is in use, and a tool which has a tip outside the casing and which forms part of a mass loaded-ultrasonic transducer system, the system comprising, in addition to the tool, a mass-loaded piezoelectric ultrasonic transducer and a stepped ultrasonic vibration transmitter and amplifier which supports the tool and abuts said transducer so that it transmits to the tool ultrasonic vibrations generated by said transducer and amplifies those vibrations whilst transmitting them, the mass-loaded piezoelectric transducer and at least a major part of the stepped ultrasonic vibration transmitter and amplifier being housed within the hollow casing.

Preferably the thickness of the piezoelectric material element of the mass-loaded piezoelectric ultrasonic transducer as measured in the direction of transmission to the tool of ultrasonic vibrations generated by it is minimised.

Conveniently the mass-loaded piezoelectric ultrasonic transducer and the stepped ultrasonic vibration transmitter and amplifier are supported together within the casing by a commom support. Preferably the common support allows a limited amount of movement relative to the casing of the transducer and the stepped transmitter and amplifier together in the direction in which vibrations generated by the transducer are transmitted to the tool. Preferably the common support is located within the casing between the plane of the node of minimum amplitude of the stepped transmitter and amplifier and the coupling between the tool and the stepped transmitter and amplifier.

One form of instrument in which this invention is embodied is described now by way of example with reference to the accompanying drawing, which is a longitudinal section of the instrument.

The drawing shows that the instrument comprises a mass-loaded ultrasonic transducer system 10 housed in a hollow casing 11. The system 10 includes a detachable tubular tool 12 to which ultrasonic vibration generated by the system are transmitted. The tool 12 has a tip 13 outside the casing 11.

The casing 11 comprises a tubular main casing part 14 which is designed to be held in the user's hand, a tubular closure 15 and a detachable nose cone 16, each of which is conveniently formed of a plastics material.

The main casing part 14 has an end wall 17 at one end and is internally screw threaded at the other end. A hole 18 is formed at the centre of the end wall 17. An externally threaded tubular bush 19 is screwed into the internally threaded end of the main casing part 14 so that it projects from the main casing part 14. A diametral slot 21 is formed in the end face of the bush 19 that is within the main casing part 14.

The tubular closure 15 comprises a central annular disc portion 22, an internally screw threaded tubular portion 23 which projects in one

direction from the outer edge portion of the central disc portion 22 and an externally screw threaded, smaller diameter tubular portion 24 which projects in the opposite direction from the inner edge portion of the central disc portion 22. The larger diameter tubular portion 23 is screwed onto the portion of the tubular bush 19 that projects from the casing 11, and the central disc portion 22 abuts the tubular bush 19. A circumferentially-extending groove 25 in the inner surface of the disc portion 22 accommodates an 'O' ring 26. The detachable nose cone 16 is screwed onto the smaller diameter tubular portion 24.

As well as the tool 12, which projects from the nose cone 16, the mass-loaded ultrasonic transducer system 10 comprises a pair of piezoelectric ceramic rings 28 and 29; a tubular metal body 31 which has a stepped outer cylindrical surface, which supports the tool 12 at one end and which abuts one, 29 of the piezoelectric ceramic rings intimately at its other end which is larger; a tubular metal body 32 which has a right cylindrical outer surface; a pair of electrical terminals 33 and 34; and a hollow setscrew 35. The terminal 33 is sandwiched between the rings 28 and 29 which in turn are sandwiched between the tubulur bodies 31 and 32. The terminal 34 is clamped between the head of the setscrew 35 and the end face of the tubular body 32 remote from the piezoelectric ceramic rings 28 and 29. The setscrew 35 passes through the central bores of the tubular body 32 and the rings 28 and 29 and is screwed into a tapped portion of the bore of the externally stepped tubular body 31, thereby clamping the body 32, the rings 28 and 29, the terminals 33 and 34 and the body 31 together end to end. A tubular connector 36 which is adapted to receive a flexible pipe (not shown), is formed on the end face of the head of the setscrew 35 so that it communicates with the bore of the setscrew 35 and projects towards the end wall 17. A sleeve of electrically insulating material (not shown) is provided between the ceramic rings 28 and 29 and the setscrew 35.

The piezoelectric ceramic rings 28 and 29 employed should be as thin as they reasonably can be without deleteriously effecting the efficiency of their performance as an ultrasonic transducer and without undesirably reducing their ability to dissipate heat generated when operating as an ultrasonic transducer. Their outside diameter is substantially the same as that of the tubular body 32 and as that of the largest diameter portion 37 of the body 31 that they abut.

The smallest diameter portion 38 of the body 31, which is the portion to which the tool 12 is connected detachably, is connected to the largest diameter portion 37 by a medial diameter portion 39 which is a sliding fit in the bore of the tubular bush 19. The medial diameter portion 39 carries a cross-pin 41 which projects from it radially and which is located within the diametral slot 21 so that the body 31 is located against rotation within the casing 14. The axial length of the smallest diameter portion 38 of the body 31 is approximately one third that of the medial diameter portion 39 which in turn is approximately one and a half times the axial length of the largest diameter portion 37. The body 32 is a little longer than the largest diameter portion 37 of the body 31.

A circumferential groove 42 is formed in the outer surface of the medial diameter portion 39 adjacent the smallest diameter portion 38 and receives the 'O' ring 26. The axial length of the groove 42 is approximately twice the thickness of the 'O' ring 26 as measured in that direction. The diameter of the base of the groove 42 is greater than the inside diameter of the 'O' ring 26 when the elastomeric material of that 'O' ring is relaxed. Hence the 'O' ring 26 is compressed and thereby clamped between the body 31 and the closure 15.

The tool 12 includes a large tubular portion 43 which has a cylindrical outer surface and which is screwed into the end of the smallest diameter portion 39 of the body 31, a small tubular portion 44 which forms the tip 13 and a middle portion 45 which has a tapered outer surface.

The terminals 33 and 34 are connected to a suitable source of alternating electrical potential when the instrument is used. Also the connector 36 is connected into a fluid system so that liquid or gas can be caused to flow to or from the tip 13 through the system 14 as required when the instrument is being operated. The electrical leads and the fluid pipe are led through the hole 18. There are two parallel paths between the terminals 33 and 34 for electric current, one comprises the body 32 and the piezoelectric ceramic ring 28 whilst the other comprises the setscrew 35, the body 31 and the piezoelectric ceramic ring 29. Ultrasonic vibrations generated by the application of the alternating electrical potential to the two piezoelectric ceramic rings 28 and 29 are transmitted to the tool tip 13 by the stepped body 31 and the remainder of the tool 12 and are amplified whilst being so transmitted. The intimate contact between the piezoelectric ceramic ring 29 and the body 31 permits transmission of the vibrations from the ring 29 to the body 31 readily.

The acoustic arrangement of the ultrasonic transducer system 10 comprises a series arrangement of three resonantly matched half-wave resonators; the two piezoelectric ceramic rings 28 and 29 and the tubular body 32 that provides mass loading for them comprise one, whilst the tubular body 31 and the portions 43 and 45 of the needle 12 together constitute the other two. Theoretically the anti-node between the two resonators formed bu the body 31 and the needle 12 should be at the connection between the needle 12 and the body 31.

The combination of the thin piezoelectric ceramic rings 28 and 29, the mass loading provided by the tubular body 32 and the stepped

ultrasonic vibration amplifier and transmitter that comprises the body 31 and the portions 43 and 45 of the tool 12 leads to the transducer system 10 having a very high mechanical Q factor. This reduces the criticality of the accuracy of the location of the support for the transducer system 10 in relation to a nodal plane and thus enables that support to be located nearer to the coupling between the tool 12 and the stepped body 31 than would otherwise have been the case with the consequent advantage that resistance to flexing of the tool 12 at the tip 13 is increased.

The sliding fit of the body 31 in the bush 19 leads to the transducer system 10 being allowed to float linearly in its support to the limited extent permitted by flexure of the compressed 'O' ring 26. Hence undesirable mechanical damping of the ultrasonic vibrations by the means by which the system 10 is mounted within the casing 11 is minimised.

Other forms of piezoelectric elements can be used instead of the piezoelectric ceramic rings described. For example, piezoelectric ceramic tubes might be used or, where it is not intended to provide a central fluid flow passage through the instrument, one or more piezoelectric ceramic discs might be used. The piezoelectric elements, the body by which they are mass loaded and the stepped amplifier and transmitter body may be joined together by a peripherally bolted flange arrangement or by a screwed ferrule instead of by the setscrew described.

An advantage that follows from the ultrasonic transducer system having a high mechanical Q factor is that the system can be matched to an electrical exciting frequency which does not correspond to the half wave mechanical resonant frequency. A transverse motion of the tool tip will be produced if the instrument is fitted with a tool that has a bend near to its tip and an electrical exciting frequency corresponding to a mechanical anti-node at that bend is used. Such a transverse tool tip motion may be used for scraping or burnishing a solid surface.

Claims

1. An instrument comprising a hollow casing, which is to be held by hand when the instrument is in use, and a tool which has a tip outside the casing and which forms part of a mass loaded ultrasonic transducer system, the system comprising, in addition to the tool, a mass-loaded piezoelectric ultrasonic transducer and a stepped ultrasonic vibration transmitter and amplifier which supports the tool and abuts said transducer so that it transmits to the tool ultrasonic vibration generated by said transducer and amplifiers those vibrations whilst transmitting them, the mass-loaded piezoelectric transducer and at least a major part of the stepped ultrasonic vibration transmitter and amplifier being housed within the hollow casing.

2. An instrument according to claim 1 wherein the thickness of the piezoelectric material element of the mass-loaded piezoelectric ultrasonic transducer as measured in the direction of transmission to the tool of ultrasonic vibration generated by it is minimised.

3. An instrument according to claim 1 or claim 2 wherein the mass-loaded piezoelectric ultrasonic transducer and the stepped ultrasonic vibration transmitter and amplifier are supported together within the casing by a common support.

4. An instrument according to claim 3 wherein the common support allows a limited amount of movement relative to the casing of the transducer and the stepped transmitter and amplifier together in the direction in which vibrations generated by the transducer are transmitted to the tool.

5. An instrument according to claim 3 or claim 4, wherein the common support is located within the casing between the plane of the node of minimum amplitude of the stepped transmitter and amplifier and the coupling between the tool and the stepped transmitter and amplifier.

6. An instrument according to any of claims 1 to 5 wherein the transducer comprises two piezoelectric material elements sandwiched between the transmitter and a body which forms part of the mass-loaded ultrasonic transducer system.

7. An instrument substantially as hereinbefore described with reference to the accompanying drawings.

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